SNOW AND RECORD COLD IN WYOMING AND MONTANA, JUNE 1-3, 1951

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INTRODUCTION

Unusually low temperatures—accompanied by snow at some stations—occurred over Wyoming and Montana during the first 3 days of June. At many places the minima equalled or exceeded the lowest temperature ever recorded for the month. The cold weather was associated with a surface anticyclone which moved southwest out of Canada, through Montana, south and east into Wyoming, and then eastward across South Dakota. The drop in temperature was intensified by the adiabatic expansion of the air as it moved up-slope over the Plains and the eastern Rocky Mountains. The snowfall occurred principally over Wyoming where the up-slope motion was most intense.

CONDITIONS PRECEDING THE COLD WEATHER

During the last 2 days of May a center of low pressure, in an upper air trough over central Canada, moved northeast across the provinces of Saskatchewan and Manitoba. A continuation of the trough extended southwest from the Canadian Low to the Oregon coast. A large, warm ridge was increasing in strength some 200 to 300 miles west of the British Columbia and Washington State coastlines. The pattern produced by these two large features resulted in northerly winds over all of western Canada and eastern Alaska. Consequently, strong advection of cold air from the surface to the middle troposphere occurred southward over Canada and turned cyclonically as it approached the United States border near eastern Montana. Meanwhile, a low center developed over Oregon at the 700-mb. level on May 30, and moved east and southeast over Oregon and Idaho during the following 2 days.

CONDITIONS DURING THE COLD SPELL

Figure 1 shows the 700-mb. chart for June 1 at 1500 GMT, at which time the Low was centered over northwestern Colorado, and an off-shoot of the Pacific ridge had moved inland over southern British Columbia. These features controlled the circulation over the Plateau and the Pacific Coast States. The associated contour gradient at the 700-mb. level diverted part of the deep, broad flow of Polar air from Canada and directed it southwestward over Montana and Idaho, and thence south over Nevada. The cold air advection swept far to the south with below freezing temperatures over central Arizona. During the 3-day period, many raob stations in the Plateau area had record or near record low temperatures at the 500- or 700-mb. heights [1].

The ridge over the northern border of Montana and the trough running southwestward from the low center in the United States were jointly responsible for the cold air invasion over the Plateau. Without the appended trough, the ridge and low center aloft could have been expected to deflect the air flow to the east and southeast along the east side of the Divide. Such a flow would have moved the cold tongue east from the Plateau region and on to the Plains, during the course of the next 2 days, as the low center moved to the northeast.

The chart for June 2 at 1500 GMT (fig. 2), shows the cold tongue had remained over the Plateau as the Low moved rapidly northeastward to near Fargo, N. Dak. As can be seen, the trough on the southwest side of the Low and the ridge to the northwest caused cold northeast winds

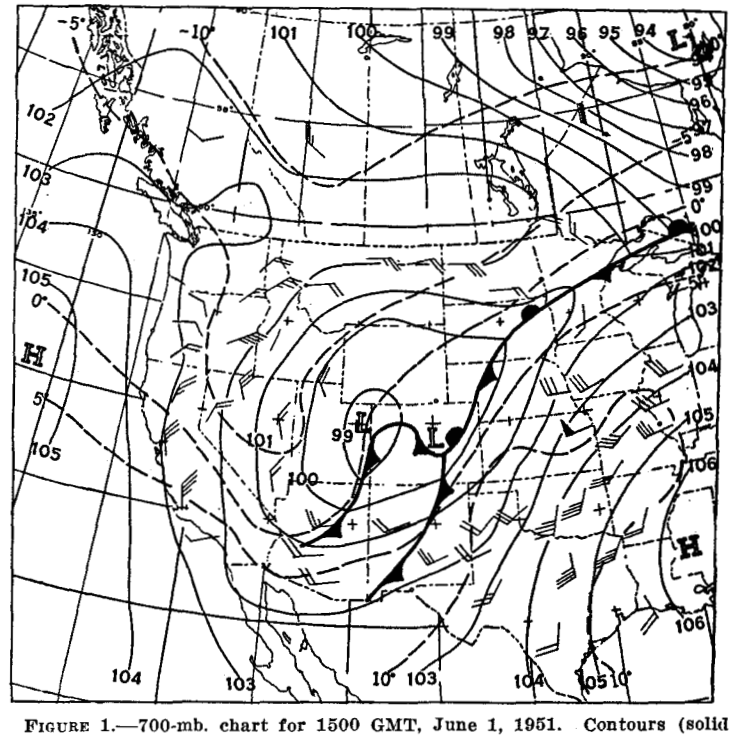

FIGURE 1.—700-mb. chart for 1500 GMT, June 1, 1951. Contours (solid lines) at 100-foot intervals are labeled in hundreds of geopotential feet. Isotherms (dashed lines) are at intervals of 5° C. Barbs on wind shafts are for speeds in knots (pennant=50 knots, full barb=10 knots, and half barb=5 knots).

of considerable depth to flow southwestward over Montana and into Colorado and Utah.

Winds at the 700-mb. surface shifted to a more westerly direction during the next 24 hours as the heights rose over the Plateau and the Western Plains. Figure 3 illustrates the new pattern on June 3 at 1500 GMT, showing clearly the advance of the cold tongue—now east of the Divide—with freezing temperatures as far south as the New Mexico-Colorado border. Over western Montana the trend toward rising temperatures had already set in. In the next 24 hours, the cold tongue moved east and the freezing isotherm retreated to the latitude of North Platte, Nebr. Over the Plateau the temperatures rose as the air came from the south and southwest.

During the 3-day period the temperature over Montana, Wyoming, and Colorado remained almost consistently cold at the 700-mb. level with readings of −5° to −10° C.

The soundings at Rapid City, S. Dak., (fig. 4), were selected to represent the vertical structure of the Polar air in the lower and middle troposphere. Ascents on June 1 and June 2 indicated cooling and increasing depth of the turbulent layer from the surface to near the 700-mb. level. The depth of this layer of steep lapse rate permitted only small daytime increases in surface temperatures. Although the cooling was less pronounced above 700 mb., the two curves show that it extended well up into the troposphere. The curve for June 3 shows warming from the surface up to near 700 mb., but cooling from this level to 400 mb., especially being 700 and 500 mb. The latter sounding also indicated the surface turbulent layer was losing definition along its upper boundary as the air above 700 mb. approached dry adiabatic lapse rate conditions.

Although the soundings for Great Falls, Mont. (fig. 5), were in the same air mass as those for Rapid City, they show interesting differences. Comparing the soundings for June 1 and 2 it can readily be seen that the air became warmer between the surface and 700 mb. at Great Falls. Then it alternately cooled and warmed from the 700- to 500-mb. level. Over the remaining 150 mb. the temperatures remained about the same. From June 2 to 3, warming took place from the surface upward to near 600 mb., but the layer above 600 mb. cooled, with the result that the lapse rate of the entire column of air approached the dry adiabatic lapse rate.

Investigation as to the cause, or causes, of this warming near the surface was carried out by tracing the trajectory of the air. A cursory examination of the surface maps would indicate that the air had moved up-slope over Montana with consequent cooling. However, an air parcel located just northwest of Aberdeen, S. Dak., on June 1, was traced along a path that led to Rapid City. During the travel the air moved 2,000 feet uphill and cooled 10° F. From Rapid City, the air streamed west and uphill through eastern Wyoming. When about half way between the eastern border of Wyoming and the Divide, it curved slowly clockwise and moved northwestward in the vicinity of Cody, Wyo. Shortly after leaving Cody, the air reached its highest point where the ground elevation reached 9,000 feet, on the Montana-Wyoming border. The parcel which had had a temperature of 36° F. was now down to 31°. During the next 12 hours the air underwent adiabatic compression as it descended 5,400 feet to a point near Livingston, Mont., at which place the temperature read 45° F. After another 24 hours of downhill travel the air parcel was traced to the area west of Glasgow, Mont., with a temperature of 69° F.

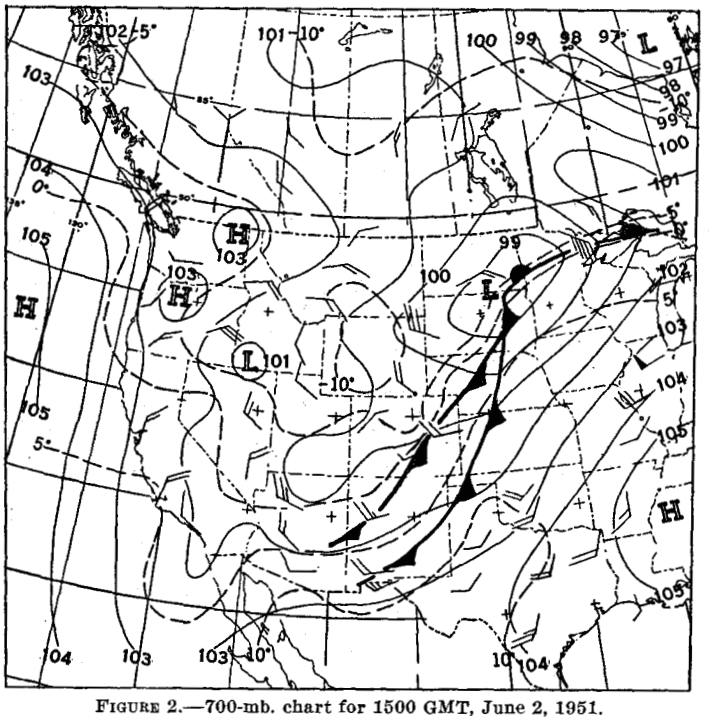

FIGURE 2.—700-mb. chart for 1500 GMT, June 2, 1951.

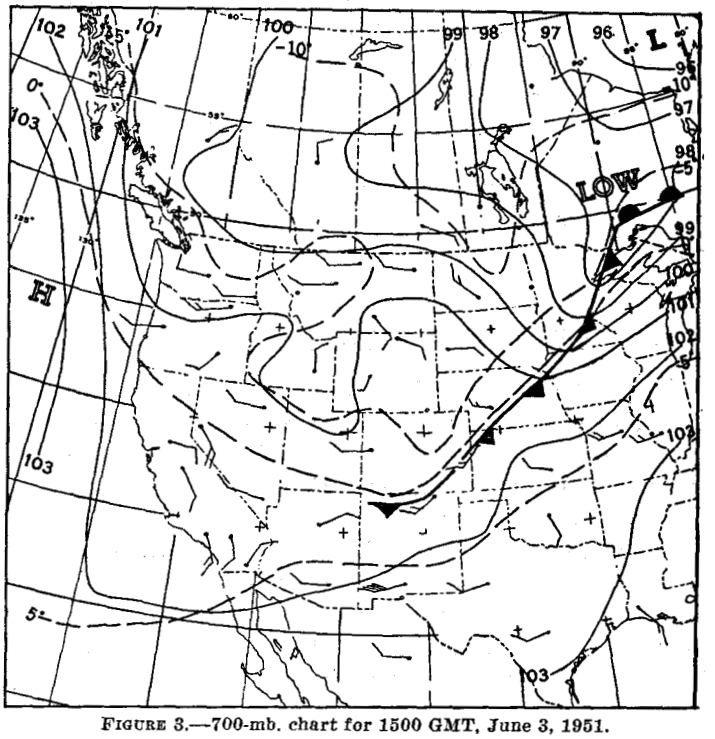

FIGURE 3.—700-mb. chart for 1500 GMT, June 3, 1951.

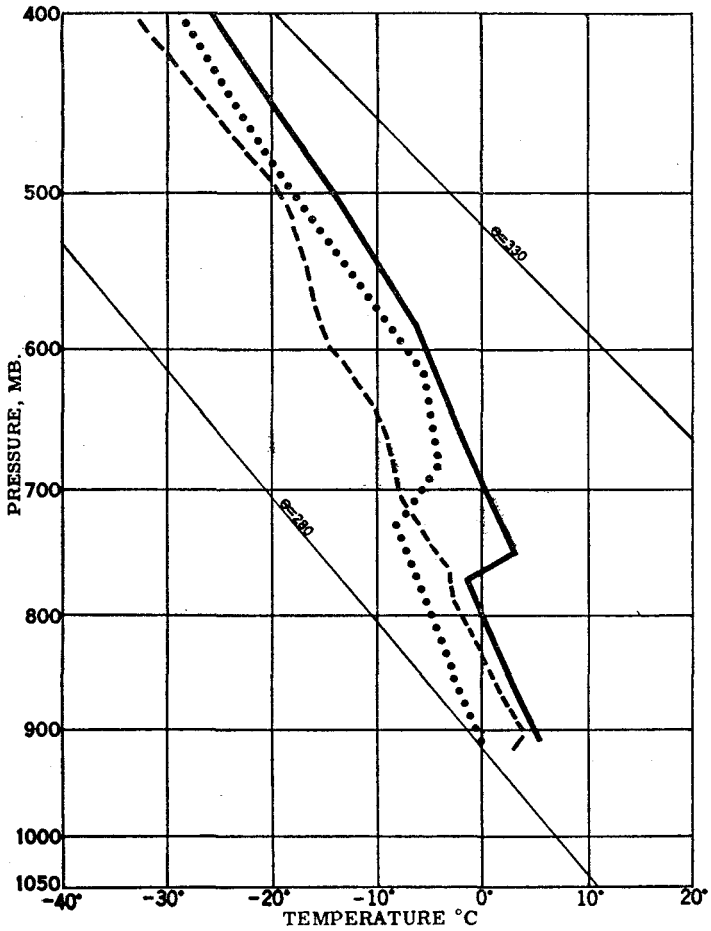

FIGURE 4.—Upper air sounding—Rapid City, S. Dak., at 0300 GMT, on June 1 (solid line), June 2 (dotted line), and June 3 (dashed line).

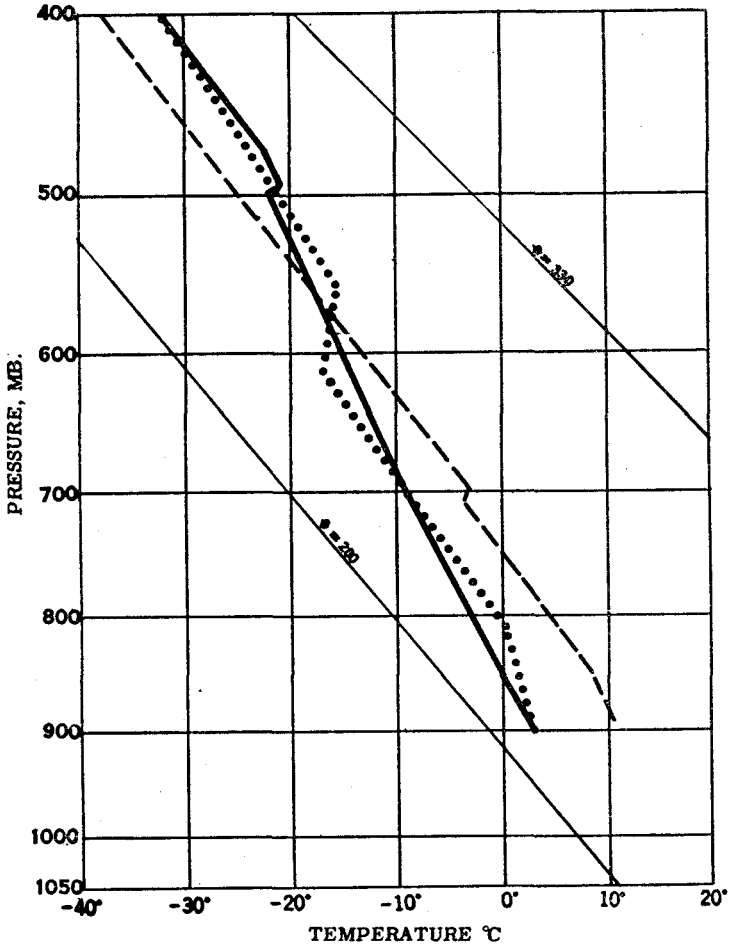

FIGURE 5.—Upper air soundings—Great Falls, Montana, at 0300 GMT, on June 1 (solid line), June 2 (dotted line), and June 3 (dashed line).

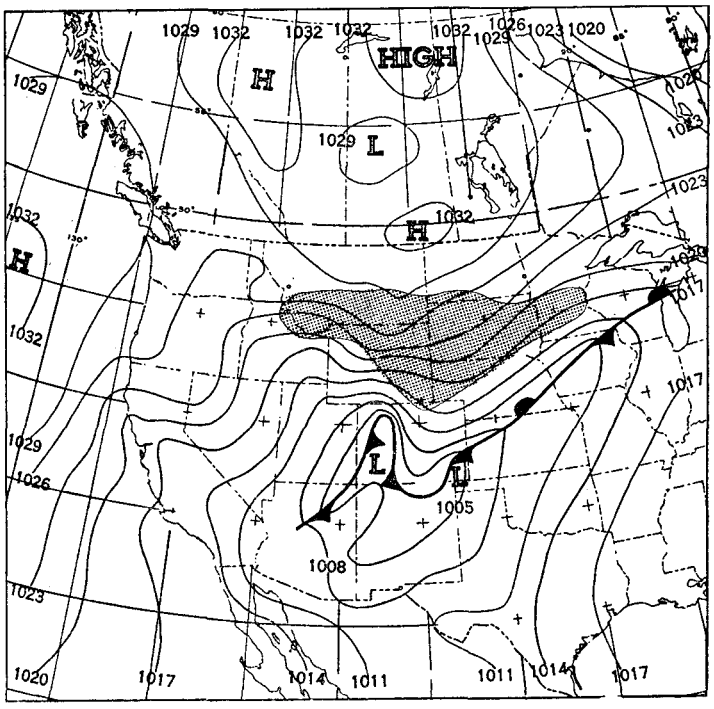

FIGURE 6.—Surface weather chart for 1230 GMT, June 1, 1951. Shading indicates areas of active precipitation.

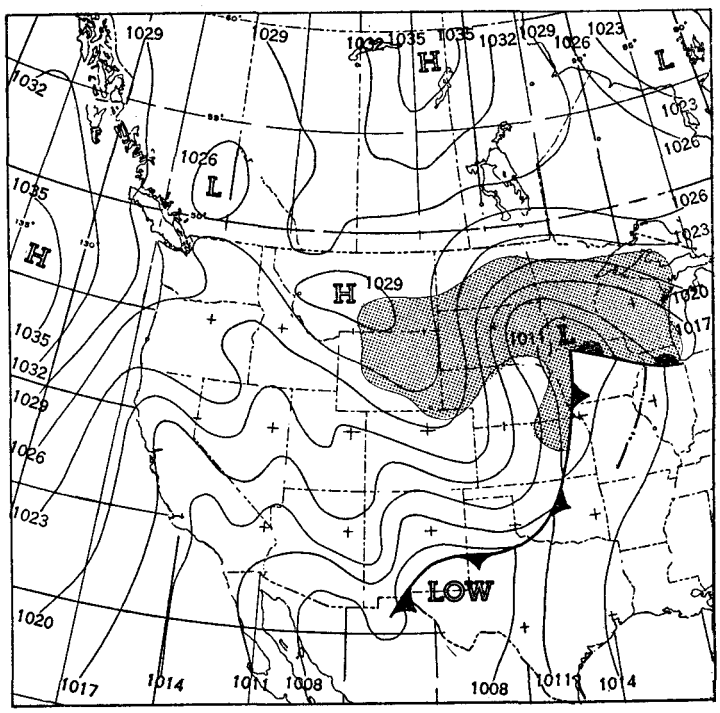

FIGURE 7.—Surface weather chart for 1230 GMT, June 2, 1951.

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No attempt is being made here to explain why the air cooled only 5° F. on its travel from Rapid City to Cody, while undergoing a net rise in excess of 3,000 feet altitude. Nevertheless, some suggestion of the answer is contained in the facts that the moisture was being precipitated out along this leg of the course and, in addition, the air had not moved uniformly upward. Actually it rose to 7,000 feet and descended to 5,000 feet with the latent heat of condensation being added to the air that rose, once again, before reaching Cody. The downhill leg from Cody was made under clear skies; and the related temperature rise was intimately connected with insolation, warmer ground surface, and adiabatic compression.

This last statement, then, explains why the air over western Montana became warmer during the 3 days of the cold spell. Conversely, the air remained quite cool over eastern Wyoming because of adiabatic cooling, overcast skies, a cold ground surface, and snow cover.

SURFACE SYNOPTIC CONDITIONS ACCOMPANYING THE COLD WEATHER

On June 1 (fig. 6), the mass of continental Polar air moved into the northern plains as a surface reflection of the circulation at higher levels. The anticyclonic circulation moved air across the plains and up-slope over the foothills and uplands to, finally, the Divide, with resulting extensive cloud cover and precipitation. During the first 2 days the precipitation fell mostly as snow over extreme western South Dakota, most of Wyoming, and southeast Montana. The greatest fall occurred at Lander, Wyo., which recorded a 24-hour total of 15.9 inches on June 1, and 2 inches on June 2. The following is quoted directly from the station summary [2]. "The heavy, wet snow that fell on the last of May and June 1 and 2 brought a total of 22.1 inches, the heaviest late snowfall on record. Telephone and electrical service was interrupted for several days. Trees and shrubs were broken and an estimated loss of $35,000 was suffered in this area." The greatest depth on the ground during this storm was 11 inches on June 1.

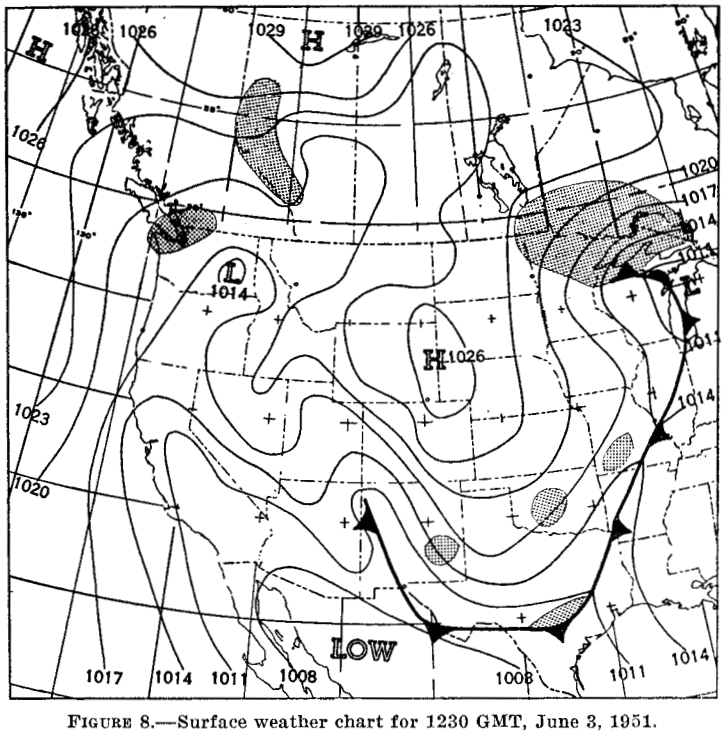

FIGURE 8.—Surface weather chart for 1230 GMT, June 3, 1951.

Rock Springs, Wyo., had a total of 0.4 inch and Sheridan, Wyo., had 3.2 inches of snow on the first of June. At Sheridan it was the greatest monthly total for June so far recorded [3]. Casper, Wyo., had 1.5 inches on the first, while Cheyenne, Wyo., had trace amounts during the period. Rapid City had a fall of 3.6 inches on June 1, which was the first measurable June snowfall in the 63-year history of that station. The weather map for June 2 (fig. 7), represents the synoptic conditions 3 hours before the snow stopped falling over most of the area, although instability snow showers continued over Wyoming until midafternoon, local time.

The maps for June 2 (fig. 7), and June 3 (fig. 8), show the surface situation at the time of the lowest minimum temperatures. Considering the stations for which records were available, many had their lowest temperatures on June 2, while under overcast skies and falling rain or snow. The minimum temperatures at many stations were the same or slightly higher on June 3, despite radiation into cloudless skies. On June 4 (not shown), the High moved into southeastern South Dakota and the temperatures began rising over the northern Plains and the Plateau States.

The following tabulation presents the low temperatures reached at representative stations in the area during the first 3 days of June:

TABLE 1.—*Low temperatures, June 1–3, 1951*

Station	June 1	June 2	June 3	Previous June minimum of record
	°F.	°F.	°F.	°F.
Billings, Mont.	32	32	32	32
Butte, Mont.	30	25	24	23
Casper, Wyo.	30	28	30	32
Cheyenne, Wyo.	27	25	31	28
Glasgow, Mont.	30	43	37	32
Great Falls, Mont.	34	33	42	31
Helena, Mont.	34	34	31	31
Kalispell, Mont.	28	30	38	31
Lander, Wyo.	29	27	25	26
Missoula, Mont.	31	31	35	30
Rapid City, S. Dak.	31	31	33	32
Rock Springs, Wyo.	28	26	26	27
Sheridan, Wyo.	32	30	27	29

In addition, Goodland, Kans., had a new record low for June of 31° on June 2—the previous low having been 36°.

REFERENCES

1. U. S. Weather Bureau, "Extreme Temperatures in the Upper Air", *Technical Paper No. 3*, Washington, D. C., July 1947.
2. U. S. Weather Bureau, *Station Meteorological Summary*, Lander, Wyoming, June 1951 (W. B. Form 1001-C).
3. U. S. Weather Bureau, *Local Climatological Summary with Comparative Data, 1950* (for individual stations).

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